“Species extinction on islands: canaries in the coalmine”

Quentin Cronk
UBC, RBG Kew
A world in miniature

• Continents have vast areas – difficult (but not impossible) to destroy all natural vegetation
• Continental organisms have relatively vast population sizes – difficult to push to extinction
• Islands are small – impacts are comprehensive
• Island organisms have relatively small total populations – easy to push to extinction

Dialogue, discussion, systems approach
Ecological disaster starts in 1502
Soil washed into the sea

Now: c. 97% of natural habitat lost
“Dwarf ebony” or “silver-leaved blackwood” is extinct (*Trochettiopsis melanoxyylon*) - extinct by c. 1790
# The Extinct Plants of St Helena

<table>
<thead>
<tr>
<th>Species</th>
<th>Endemic genus</th>
<th>Date</th>
<th>Cultivated</th>
</tr>
</thead>
<tbody>
<tr>
<td>She cabbage tree</td>
<td>yes (monotypic)</td>
<td>2012</td>
<td>Yes (EW)</td>
</tr>
<tr>
<td>St Helena Olive</td>
<td>yes (monotypic)</td>
<td>2002</td>
<td>No (EX)</td>
</tr>
<tr>
<td>St Helena redwood</td>
<td>yes</td>
<td>1960</td>
<td>Yes (EW)</td>
</tr>
<tr>
<td>Burchell’s bellflower</td>
<td>no</td>
<td>1880</td>
<td>No (EX)</td>
</tr>
<tr>
<td>Stringwood</td>
<td>no</td>
<td>1871</td>
<td>No (EX)</td>
</tr>
<tr>
<td>Roxburgh’s bellflower</td>
<td>no</td>
<td>1840</td>
<td>No (EX)</td>
</tr>
<tr>
<td>St Helena heliotrope</td>
<td>no</td>
<td>1820</td>
<td>No (EX)</td>
</tr>
<tr>
<td>Dwarf St Helena ebony</td>
<td>yes</td>
<td>1790</td>
<td>No (EX)</td>
</tr>
</tbody>
</table>
Cultivation: a warning

Botanic Garden Accessions (Edinburgh)
St Helena Olive (*Nesiota elliptica*) – monotypic endemic genus

EXTINCT – A sad loss

Photo: Marcella Corcoran
MAMP = microbe-associated molecular pattern
PRR = Pattern recognition receptor (kinases, pattern-triggered immunity – PTI)
NLR = NBS-LRR domain gene (effector triggered immunity – ETI)
Some concepts: Living dead

• “An individual stripped of the ecological circumstances that allow it to be a reproductive member of its population, but which is living out its physiological life. Living dead are most easily observed as large trees remaining on the agroscape” (D.H. Janzen)

(1) Loss of functioning ecosystem
(2) Genetic damage

Rainforest relict in the Costa Rica agroscape

Photo: David Zabner
Latent extinction - reduction of all populations of a species to ‘living dead’

“We live a perceptual lie as we bustle about our agroscapes. That single stately green *Dipteryx* or *Hymenaea* or *Swietenia* or *Enterolobium*, standing in a field, pasture, or roadside, is often just as dead as if it were a log in the litter or the back of a logging truck.” – *D.H. Janzen*
Why does plant extinction take so long?

- **Relaxation time** – extinction lag time, i.e. time to equilibrium (Jared Diamond 1972)

- **Extinction debt** – number of latently extinct species in a perturbed, but still equilibrating, ecosystem (David Tilman 1994). Species in the extinction debt are those committed to extinction but not yet extinct
How do we pay off extinction debt?

• Capacity to **self-sustain populations**
• Capacity to **adapt to changing environments**. (The environments in which St Helena species evolved no longer exist)
• Capacity to **provide ecosystem function**
• Connection with people
Action

- **functional ecosystem** to provide ecological function (ecological restoration) – Peaks team, Millennium Forest

- **functional genome** to provide genetic fitness and evolvability (genetic restoration) – rosemary polycross

- **community engagement** – open days, volunteer groups, dialogue, buy in
FROM THE COVER

Genetic rescue of small inbred populations: meta-analysis reveals large and consistent benefits of gene flow

RICHARD FRANKHAM*†
*Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia, †Australian Museum, 6 College St, Sydney, NSW 2010, Australia

Abstract

Many species have fragmented distribution with small isolated populations suffering inbreeding depression and/or reduced ability to evolve. Without gene flow from another population within the species (genetic rescue), these populations are likely to
Adaptive introgression as a resource for management and genetic conservation in a changing climate

Jill A. Hamilton*† ¶ and Joshua M. Miller‡

*Department of Evolution and Ecology, University of California, Davis, CA, 95616, U.S.A.
†Department of Biological Sciences, North Dakota State University, Fargo, ND, 58102, U.S.A.
¶Department of Biological Sciences, University of Alberta, Edmonton, Alberta, T6G 2E9, Canada

Abstract: Current rates of climate change require organisms to respond through migration, phenotypic plasticity, or genetic changes via adaptation. We focused on questions regarding species’ and populations’ ability
Dedication: the success of conservation in St Helena depends on the skill and determination of St Helenians

George Benjamin and his team, 1995
Ancestral species

Species A

Species B

Resistance gene lost by inbreeding or mutation

Resistance gene replaced by introgression
St Helena
Conservation
First *T. ebenus* flower seen since c. 1860
Except...
Trochetiopsis melanoxyylon – described as “tota argentea” - is quite different from extant ebony (*Trochetiopsis ebenus*). Sadly this has never been seen since Banks and Solander collected it in the 18th century.
Ebony (*Trochetiopsis ebenus*) only found in subfossil state
The Extinct Plants of St Helena

<table>
<thead>
<tr>
<th>Species</th>
<th>Endemic genus</th>
<th>Approximate extinction date in wild</th>
<th>Cultivated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acalypha rubra</td>
<td>no</td>
<td>1871</td>
<td>No (EX)</td>
</tr>
<tr>
<td>Nesiota elliptica</td>
<td>yes (monotypic)</td>
<td>2002</td>
<td>No (EX)</td>
</tr>
<tr>
<td>Lachanodes arborea</td>
<td>yes (monotypic)</td>
<td>2012</td>
<td>Yes (EW)</td>
</tr>
<tr>
<td>Trochetiopsis erythroxyylon</td>
<td>yes</td>
<td>1960</td>
<td>Yes (EW)</td>
</tr>
<tr>
<td>Trochetiopsis melanoxyylon</td>
<td>yes</td>
<td>1790</td>
<td>No (EX)</td>
</tr>
<tr>
<td>Wahlenbergia burchellii</td>
<td>no</td>
<td>1880</td>
<td>No (EX)</td>
</tr>
<tr>
<td>Wahlenbergia roxburghii</td>
<td>no</td>
<td>1840</td>
<td>No (EX)</td>
</tr>
<tr>
<td>Heliotropium pannifolium</td>
<td>no</td>
<td>1820</td>
<td>No (EX)</td>
</tr>
</tbody>
</table>

DARK EXTINCTION?
**Trochetiopsis erythroxyylon** (St Helena redwood)

Work of Rebecca Cairns-Wicks has restored the maximum fitness but redwood still lacks “ecosystem competence” in the new highly invaded ecosystems that have replaced its natural habitats: it is an “ecological ghost” or “shadow species”

- highly inbred
- reduced in stature
- physiological symptoms
- early mortality

Interspecific hybrid (*Trochetiopsis x benjamini*) shows hybrid vigour– a magnificent, fast growing, long lived, environmentally tolerant plant

Fig. 1. A drawing by W. J. Burchell, dated 27.12.1807, of ‘The Great Redwood Tree at Longwood’. In the background are gumwood trees *Commidendron robustum*. 
St Helena Redwood (extinct in wild)

Estimated census population 1500-2015

Single plant, Peak Gut waterfall, c. 1950
Allee effect
- correlation between population size and mean individual fitness

After: Luque et al., 2016
## Table of extinction of selected St Helena plants

<table>
<thead>
<tr>
<th>Species</th>
<th>Functionally extinct</th>
<th>Census extinction</th>
<th>Cultivated</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acalypha rubra</em></td>
<td>18th C</td>
<td>19th C</td>
<td>No</td>
</tr>
<tr>
<td><em>Commidendrum rotundifolium</em></td>
<td>18th C</td>
<td>1 plant in wild</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Nesiota elliptica</em></td>
<td>19th C</td>
<td>21st C</td>
<td>No</td>
</tr>
<tr>
<td><em>Lachanodes arborea</em></td>
<td>19th C</td>
<td>21st C</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Trochetipsis erythroxylon</em></td>
<td>18th C</td>
<td>20th C</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Trochetiopsis melanoxylon</em></td>
<td>18th C</td>
<td>c. 1790</td>
<td>No</td>
</tr>
<tr>
<td><em>Wahlenbergia linifolia</em></td>
<td>20th C</td>
<td>c. 20-40 plants in wild</td>
<td>No*</td>
</tr>
<tr>
<td><em>Heliotropium pannifolium</em></td>
<td>17th C</td>
<td>c. 1820</td>
<td>No</td>
</tr>
</tbody>
</table>
Relaxation time on St Helena

• Plants functionally extinct in 18th - 19th century
• Relaxation time of 100-300 years
• 19th century extinction debt has taken up to >100 years to reach “census extinction”
Genomic selection

- Use whole genome sequencing to maximise genetic gain
Optimal contribution selection

• Optimise mating
• Maximise genetic gain while minimizing co-ancestry
• In “extinct in wild species”, such as *T. erythroxylon*, humans control all regeneration and breeding – therefore feasible to maximise genetic gain of species
Urgent research needs

- co-ordinated genomic sequencing on all “ultra-rare” or “extinct in wild” species, including historical materials
- determine inbreeding, distribution of genetic diversity between individuals, effective population size ($N_e$)
- genomics-guided genetic restoration, adaptive introgression
ACKNOWLEDGEMENTS
Living dead in botanic gardens

• Half-life of living collections low (c. 4 years)

• *Trochetiopsis erythroxyylon* [extinct in wild] has been introduced, lost and re-introduced c. 3 times at Kew; no introduction appears to have lasted more than 30 years. (Mann, D., Cronk, Q. & Rae, D. (2000) *The river of diversity: perspectives on the use and management of living collections in botanic gardens.* RBGE.)
T. ebenus formerly used for inlay work – as in this Boer war era tray
“Dwarf ebony” or “silver-leaved blackwood” (*Trochletiopsis melanoxylon*) - extinct by 1800